(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
11 April 2002 (11.04.2002)

PCT

(10) International Publication Number
WO 02/29398 A1

(51) International Patent Classification[7]: G01N 29/18, 33/46

(21) International Application Number: PCT/NZ01/00205

(22) International Filing Date: 1 October 2001 (01.10.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
507297 3 October 2000 (03.10.2000) NZ

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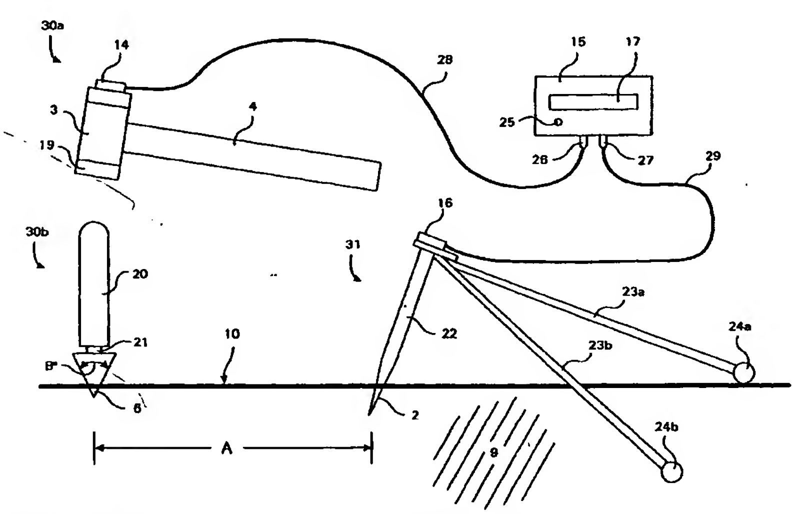
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AT (utility model), AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, CZ (utility model), DE, DE (utility model), DK, DK (utility model), DM, DZ, EC, EE, EE (utility model), ES, FI, FI (utility model), GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (utility model), SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: NON-DESTRUCTIVE TESTING OF FIBROUS MEMBERS



(57) Abstract: A method and apparatus is disclosed for the non-destructive testing of the quality of a fibrous material, such as wood (9), by the use of sound or shock waves input into the material. The shock wave is generated by striking an input means (20) against the side of the tree with a hammer (4). A first transducer (14) in communication with the input means signals when the input means is struck. The apparatus also includes a second transducer (16) in communication with a spike (22) that penetrates into the tree at a fixed distance (A) from where the input means engages the tree. The shock wave travels longitudinally along the tree, and when the shock wave reaches the spike the second transducer signals the event. The time taken for the wave to travel from the input means to the spike is measured from the time between the two transducer signals, and the velocity of the wave is calculated. The modulus of elasticity (MOE) of the wood is then determined and, thus, the quality of wood that the tree will provide is measured.

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NON-DESTRUCTIVE TESTING OF FIBROUS MEMBERS

Field of the Invention

The invention relates to an apparatus and method for non-destructive testing of fibrous material, and in particular for non-destructive testing of the quality of trees, or logs prior to milling. The expression fibrous material or fibrous member as used herein includes natural woody materials such as standing trees, logs and timber and non-wood materials such as bamboo and rattan and the expression excludes reconstituted fibrous material.

Background to the Invention

It is common practice to grade timber by visual inspection. With a visual inspection a person tries to judge the quality of a tree, log or dressed timber by its apparent surface defects. This traditional method is imprecise and, as it is reliant on human judgement, often results in timber being graded above or below its true quality. It is more common, however, for human graders using visual inspection to overcompensate and thereby undervalue the true grade of the timber.

Methods are known for non-destructive testing of dressed timber using sonic pulses. One method is described in United States Patent No. 4,702,111 (*Holland*) which describes an apparatus and method for determining the quality of dressed timber member using Fourier analysis of a sonic wave transmitted through the timber member. A second method is described in US Patent No. 5,275,051 (*De Beer*) which describes measuring the velocity and attenuation of a sonic signal transmitted though a railway sleeper. The results of these tests are used to determine the condition and life expectancy of the sleeper. However, these known methods are only effective with dressed timber and it would be advantageous to have an apparatus and method for non-destructive testing of logs prior to milling, or even trees prior to felling.

Therefore, it is an object of the present invention to provide an apparatus and method for the non-destructive testing of trees or logs which overcomes or

ameliorates some of the disadvantages with the prior art or at least provides a useful alternative.

Summary of the Invention

According to a first aspect of the invention there is an apparatus for non-destructive testing of the quality of a fibrous material:

an input means for inputting a sound or shock wave into a fibrous material,
a first transducer in communication with the input means for determining when the sound or shock wave is input into the fibrous material,
a spike for penetrating into the fibrous material at a known distance from the input means,
a second transducer in communication with the spike for determining when a sound or shock wave has reached the spike, and
a processing means for measuring the time between a signal from the first transducer and a signal from the second transducer; and
an output for indicating the absolute or relative quality of the fibrous material.

The term quality as used in this specification means the intrinsic stiffness or modulus of elasticity (MOE) of the fibrous material. The modulus of elasticity has a direct effect on other closely associated intrinsic properties of fibrous materials. These associated properties include: strength (bending, tensile, compression and shear strengths); fibre/tracheid length; cell wall thickness; microfibril angle; and density.

The sound or shock wave preferably contains components predominately below 3 KHz.

Preferably the input means includes:

an input member having an inverted cone at a first end thereof and a striking surface at a second end thereof;

a striking member adapted to strike the striking surface; and wherein the tip of the inverted cone is sufficiently sharp so as to penetrate any surface material on the fibrous material but not so sharp as to be driven more than a 10 mm depth into the fibrous material by strikes of the striking member on the striking surface.

Preferably the first transducer is in communication with the striking member.

In one embodiment the apparatus has an elongate body of known length, the input means being disposed at a first end of the body and the spike being disposed at the second end of the body.

Preferably the input means has a striking means which has an arm which is pivotably engaged with the elongate member at a first end and has a striking member at a second end, there being a mechanism for pivotably moving the striking means so that the striking member can be caused to strike the surface of the fibrous material thereby imparting a sound or shock wave into the fibrous material.

Preferably the striking member has an acute angled striking face thereby imparting the sound or shock wave into a small surface area.

In an alternative embodiment the striking means may be a mechanical or electromechanical solenoid which can be activated to strike the surface of the fibrous material thereby imparting a sound or shock wave into the fibrous material.

In a further alternative embodiment the apparatus may include an inverted cone for penetrating into the fibrous material, the striking means being adapted to strike the striking surface to impart a sound or shock wave into the fibrous material.

Preferably the inverted cone is disposed at the first end of the elongate body.

Preferably the apparatus also includes a means for determining the location of a fibrous material, preferably a Global Positioning System, and an information storage means wherein the location and quality of one or more fibrous materials can be stored for retrieval at a later date.

Preferably the output is a display which indicates a numerical or percentage value representing the absolute or relative quality of the fibrous material. Alternatively, the display may have one or more illumination means for representing the absolute or relative quality of the fibrous material.

In a further aspect the invention provides for a method of testing the quality of a fibrous material using an apparatus as hereinbefore defined.

Preferably the method includes inserting a spike through any surface material and into the fibrous material of a fibrous member; creating a sound or shock wave in the fibrous member at a known distance from the spike; determining the time taken for the sound or shock wave to travel through the fibrous material of the fibrous member from the input point to the spike; and relating the time taken to reference information to obtain an estimation of the absolute or relative quality of the fibrous member.

Preferably the reference information is the skill and experience of a person. Alternatively the reference information is historical data stored in computer readable format.

Preferably the method is adapted so that the sound or shock wave travels along the grain of the fibrous member.

Preferably the fibrous member is a tree, or a log prior to milling. More preferably the fibrous member is a tr e prior to felling.

Preferably the fibrous member is a wooden member, more preferably a tree or log,

and the fibrous material is the cambium of the wooden member.

In a third aspect the invention provides for a method of managing a plantation of trees or a forest including testing the quality of one or more trees using an apparatus or method as hereinbefore defined and adapting a management strategy depending on the results of the test(s).

Further aspects of the invention will become apparent from the following description which is given by way of example only to illustrate the invention.

Brief Description of the Drawings

The invention will now be described with reference to the accompanying drawings in which:

Figure 1 illustrates a first, preferred, embodiment of apparatus according to the invention;

Figure 2 illustrates a second embodiment of an apparatus according to the invention; and

Figure 3 illustrates a third embodiment of an apparatus according to the invention.

Description of the Preferred Examples

In order to avoid under-grading or over-grading timber it is necessary to know what load the timber can carry before it will break. This requires knowledge about the actual strength characteristics of the timber along its entire length. The point at which a length of timber will break is called its modulus of rupture (MOR).

A non-destructive test to determine the rupture point of a length of timber has not yet been found. However, it is known that there is a direct proportional relationship between the amount of bend applied to a length of timber and the point at which it will break. The forc required to bend a length of timber by a predetermined amount is called its modulus of elasticity (MOE). MOE is a very important structural property. For example, the sagging of roof and floor members

results from low rigidity. MOE measures how rigid a material is. Therefore, if the MOE can be measured in a non-destructive manner this can be used to estimate the quality of the timber.

The speed at which sound or shock waves travel through the wood in a log or tree has a direct relationship to the average MOE of the wood in the log or tree. This can be used to judge the relative relationship between one or more logs. If one of two logs, of otherwise similar visual characteristic, has an average faster speed of sound transmission then that log or tree will produce timber of a relatively superior quality than the other log or tree. By compiling a database of information relating the speed at which sound travels in the cambium of a log or tree to the quality of the timber, reference information can be established which allows the speed of sound to be used to estimate the quality of timber which might be obtained from the log. Furthermore, the speed at which sound travels throughout a small section of a log or tree is indicative of the quality of timber through the entire length of the log. Therefore, the test need not be carried out through the entire length of the log.

Figures 1 to 3, in which the same numerals represent like integers, show four embodiments of an apparatus for measuring the speed at which sound travels in the cambium of a tree or log.

Referring to Figure 1, shown is a preferred embodiment of an apparatus according to the invention. The apparatus includes a signal input means 30a, 30b, a signal receiving means 31 and a display means 15. The signal input member 30a, 30b includes two elements. The first element is an input means 30b which comprises an inverted cone 6 attached via a shaft 21 to a handle 20. The second element is the striking member or hammer 30a. Hammer 30a comprises a handle 4 extending to a head 3 with striking face 19. On the back of head 3 is a transducer 14 for detecting wh n a sound or shock wave is input into a tree cambium 9. Transducer 14 has attached a flexible cable 28 with a connector 26 for connecting to proc ssor unit 15.

In the preferred embodiment shown transducers 14 and 16 are connected to processor 15 by way of respective flexible cables 28, 29 and connectors 26 and 27. It is envisaged that in one embodiment communication of the signal may be by close proximity radio. Transducers 14 and 16 may have respective transmitters with a receiver at processor 15. While the use of radio communications may introduce a delay in the transmission of signals from transducers 14, 16 to processor 15 it is envisaged that in a preferred embodiment the indication of log quality will be relative rather than absolute and judgement will be at the discretion of a skilled and experienced operator. This is described further below. Also, allowance for the radio communication delay may be programmed into this system. It is envisaged that interpretation of relative measurements and allowance for radio delay will ameliorate any effects of radio delay on the accuracy of the apparatus.

To input a signal into the cambium 9 of a tree an operator positions the inverted cone 6 against the tree bark 10 and strikes handle 20 with hammer 30a. So that a sufficient signal is transferred into cambium 9 inverted cone 6 must have a substantially broad tip. If the tip of inverted cone 6 is too sharp it will easily pierce into the cambium 9 and little shock signals will be transferred longitudinally through the cambium 9 fibres. However, the tip of inverted cone 6 must be sufficiently sharp to pierce bark 10 and impact on cambium 9. The optimum angle B° for inverted cone 6 has been found to be in the order of 60°. Further, the inventors have found that several preliminary strikes are needed in order to pierce bark 10 and compact the surrounding wood of cambium 9. This will be discussed in more detail later.

Additionally, striking surface 19 and handle 20 must be made of appropriate material in order to create an appropriate signal source. Metal surfaces striking each other pr duce a high frequency shock wave which penetrates transversely through the cambium 9 and dissipates quickly. The inventors have found that ABS and other toughened plastic striking surfaces create a lower frequency shock

wave which travels longitudinally down the outside fibres of cambium 9 as required.

Transducer 14 detects the strike of surface 19 on handle 20. The transducer 14 could be an accelerometer or other device capable of detecting a sound or shock wave. The current embodiment uses a simple piezo-electric device. Normally these devices have a voltage applied to produce a tone. However they work adequately in reverse: detecting the shock or sound wave and producing an output signal.

Referring now to receiving means 31. Receiving means 31 is in the form of a tripod arrangement having legs 23a, 23b and 22. Leg 22 extends to a receiving spike 2 which can penetrate through bark 10 into cambium 9. Remaining legs 23a and 23b have feet 24a and 24b which rest on the outside of the tree bark 10. Feet 24a and 24b are made of rubber or other suitable materials which prevent the transfer of shock or sound waves into receiving means 31. The arrangement ensures that the first shock or sound wave can enter receiving means 31 is via spike 2 in cambium 9.

At the top of leg 22 is a second receiving transducer 16 which is connected via a cable 29 and connector 27 to processor unit 15. In the current embodiment receiving transducer 16 is also a piezo-electric device. Because of attenuation of the sound or shock wave in cambium 9 additional amplification of the signal from transducer 16 is required.

Processing unit 15 includes a micro-processor (not shown) which receives signals from transducers 14 and 16. The micro-processor manipulates the signals to give an estimation of the absolute or relative quality of the log or tree. A display 17 is provided to indicate the quality reading to a user. An on/off/reset button 25 is also provided.

The preferred embodiment of the invention is mostly suited to testing cut logs

which lay, horizontally, at a skid site of a logging operation or at a sawmill. Use of the preferred embodiment will now be described and further aspects of the invention will also become apparent.

An operator begins by placing feet 24a and 24b of receiving apparatus 31 on the side of a cut tree, or log, and piercing spike 2 of leg 22 through bark 10 and into cambium 9. Processing unit 15 can be placed in a suitable location or worn on a strap around the operators neck or on the operators belt.

The operator then holds handle 20 of input member 30b and places inverted cone 6 against bark 10 at a known, or repeatable, distance from spike 2. The operator, holding handle 4 of hammer 30a in his other hand, strikes the top of handle 20 with striking surface 19. This strike is detected by transducer 14 and recorded by the processor 15. A sound or shock wave travels through inverted cone 6 into cambium 9 and along the fibres of cambium 9 to spike 2 where it is detected by transducer 16 and recorded at the processor 15. The processor 15 determines the time taken for the shock wave to travel from inverted cone 6 to spike 2 and indicates a reading, either relative or absolute, on display 17.

At this stage it is envisaged that the first reading will be of little use in determining the quality of the log. The reason for this is that the thickness of bark 10, any air pockets, and the number of strikes of surface 19 and handle 20 will effect the reading. It is envisaged that the operator will need to strike input element 30b a number of times in order to compact the bark 10, and embed inverted cone 6 well into the cambium 9. With each strike the operator will get a reading which will eventually settle to a repeatable value that can be taken as a relative or absolute reading indicating the quality of the log.

The inventors have found that three or four strikes will generally give a settled reading. Further, acceptable r sults have been achieved with a distance between input inverted cone 6 and receiving spike 2, indicat d by distance A on Figure 1, of 1 metre. However this distance is not critical to the inv ntion.

Because a number of factors will affect the reading indicating log quality it is envisaged that the device would be used by a skilled operator who will use judgement and experience to interpret the relative or absolute reading indicating the quality of log. The factors affecting the reading include the distance between inverted cone 6 and spike 2, the thickness of bark 10, the force and number of strikes by the operator, and fibre alignment and moisture content in cambium 9. Further, longitudinal fibre orientation of a log might not be parallel with the longitudinal axis of the log. This would mean an operator might have to try inputting the sound signal at the different circumferential locations around the log until they achieve an acceptable result. While it is conceivable that a database and/or fuzzy logic model might be produced which can take account for the variables effecting the test results it is envisaged that greater accuracy and versatility will be achieved by the skilled operator

It is envisaged that the indication to the operator can be given in a number of ways. Some examples are described below.

Once the processing unit 15 has determined the time taken for the shock wave to travel from inverted cone 6 to the spike 2 it can relate this to reference information to determine an absolute or relative value of quality for the tree. This calculation could be by way of a lookup table of historical data. A display 17 is provided for outputting the relative or absolute value of the quality of the tree. This output could be by way of a numerical value or percentage. Alternatively, a predetermined/pre-set threshold value could be programmed in the processing unit 15 which would simply accept or reject the tree depending on the result of the test. The output for this alternative threshold method could be one or more coloured lights (for example red and green) indicating whether the tree is accepted or rejected. The processor 15 could have multiple pre-programmable thresholds to provide bad, medium, good results and the like. It is understood that such methods of interpreting the results of a test and indicating to an operator are well within the know how to be attributed to a skilled addressee and do not depart

from the scope of the invention.

While it is possible to have the processing module access historical data in order to give an indication of the quality of the logs. It is envisaged that in the preferred embodiment of the invention the operator would make assessment based on a numerical indication given on display 17. There are a number of factors which affect this indication including the way the grain, or fibres, of the cambium 9 are orientated, the distance and orientation between the input spike 6 and receiving spike 2, the moisture content of the timber, thickness of the bark and so on. Often the operator is in the best position to make assessment of the classification of a log.

Figure 2 illustrates a second example of an apparatus according to the invention. This comprises an elongate body 1 with a spike 2 at its lower end and a hammer 3 at its upper end. The hammer 3 comprises a handle or arm member 4 which is pivotably engaged 5 to the elongate member 1. At the second end of arm 4 is a striking member 6. The striking member 6 is tapered towards its striking surface 13. This results in a smaller contact surface area when the hammer 3 strikes a tree or log. The bark 10 is compressed and there is better transfer of the sound or shock wave into the cambium 9 of the tree or log.

In this embodiment elongate member 1 would need to be made from a material that does not conduct sound or shock waves well. Alternatively there may be an isolation point between elongate member 1 and transducers 16 and 14. This is to ensure that the shock or sound wave recorded is that which travels in cambium 9.

Near the lower end of the elongate member 1 is a handle arm 7 which is pivotably connected to the elongate member 1 at one of its ends. A lever arm 8 is pivotably connected between the handle arm 7 and arm 4 of hammer 3. This linkage arrangement - handle arm 7, lever arm 8 and hammer arm 4 - allows the hammer 3 to be operated from near the lower end of the elongate body 1. The linkage has a spring 12 biasing the hammer in the clos d position.

This apparatus is particularly adapted for testing standing trees. In use an operator, holding the apparatus in a substantially vertical orientation with the spike 2 at the lower end, pushes the spike through the bark 10 of a tree and into the cambium 9. A foot 11 supports the top of the elongate body 1 against the tree. Downwards movement of handle arm 7 draws the hammer 3 back against the bias of the spring 12. When the handle arm 7 is released spring 12 will cause the lever mechanism to retract striking face 13 of hammer 3 against the tree bark 10. The small surface area of hammer face 3 compresses the bark 10 and transfers a sound or shock wave into the cambium 9 of the tree.

Figure 3 illustrates further alternative embodiments of the apparatus. In the further alternative embodiments the apparatus has an inverted cone 18 which penetrates the bark 10 of the tree and delivers the sound or shock wave directly into the cambium 9. In this embodiment there is no need for tapering of the striking member 6 to reduce the surface area of face 13. The hammer 3 strikes the striking surface of inverted cone 18 which transfers the sound or shock wave into the cambium 9 of the tree. Hammer 3 is pivotable engaged on an arm 13 attached to elongate body 1. The first transducer 14 may be in communication with the hammer 3 as shown in Figure 3. A further variation might include replacing hammer 3 with a mechanical or electromechanical solenoid for striking the tree, as in Figure 2, or with inverted cone 18 as in Figure 3.

The above apparatus have the advantage that they can test the log or tree over a small section thereof, eg one metre, from an external position. This means that the operator undertaking testing does not require clear access to ends of a cut log and may, for example, test standing trees. Cut logs may be tested where the operator only has access to a small section through the central part of the log. It has been found that testing over a small portion, eg one metre, gives a reading which is indicative for the entire length of the log or tree.

The apparatus could also be modified to a small size to indicate the property of seedlings at nursery level, so that the poor quality stock can be sorted and

removed before planting. Research has shown that those seedlings showing good quality wood properties continue to maintain the same trend as they grow into trees.

Testing a forest according to the invention will allow the relative quality of standing trees and hence the value of the forest, to be more accurately assessed. This will allow trees of lesser quality to be identified and thinned, thus increasing the average value of the forest. Altematively, before felling the lesser value trees can be taken for chipping and shredding making access to high quality trees easier and hopefully resulting in less damage to the trees during felling. Additionally, trees of lesser quality can be identified early thus obliterating the milling of trees of inferior quality. This represents a significant added value to both timber mills and forest owners.

When trees are tested in a forest they can be marked with, say, paint to identify them in the future. In one embodiment the apparatus might also include a GPS, or other, position locating means and a data recording means. As each tree is tested its test result and location could be recorded. This information could be downloaded to a PC at a later date for use in forest management strategies (for example determining which trees to take in a selective logging environment). The locator device and data recording means could be part of the controller 15 on the apparatus. Alternatively, they could be a separate unit which is carried by the operator and communicates with the controller 15 via a patch cord or close proximity radio link. This altemative embodiment would allow flexibility of sale and use in that the apparatus could be sold as a base unit with the optional extra of carrying the locator and data recorder if this mode of operation was required.

While the invention has been described with reference to testing trees or logs and other fibrous materials such as bamboo and rattan, it is envisaged that the apparatus may find application in testing of oth r fibrous materials such as fibr glass.

Wherein the aforegoing description reference has been made to elements or integers having known equivalents, then such equivalents are included as if they were individually set forth.

Although the invention has been described by way of example and with reference to particular embodiments, it is to be understood that modifications and/or improvements may be made without departing from the scope of the invention.

CLAIMS

1. An apparatus for non-destructive testing of the quality of a fibrous material as herein defined including:

an input means for inputting a sound or shock wave into a fibrous material,

a first transducer in communication with the input means for determining when the sound or shock wave is input into the fibrous material,

a spike for penetrating into the fibrous material at a known distance from the input means,

a second transducer in communication with the spike for determining when a sound or shock wave has reached the spike;

a processing means for measuring the time between a signal from the first transducer and a signal from the second transducer; and

an output for indicating the absolute or relative quality of the fibrous material.

2. An apparatus as claimed in claim 1 wherein the input means includes:

an input member having an inverted cone at a first end thereof and a striking surface at a second end thereof;

a striking member adapted to strike the striking surface; and wherein

the tip of the inverted cone is sufficiently sharp so as to penetrate any surface material on the fibrous material but not so sharp as to be driven more than a 10 mm depth into the fibrous member by strikes of the striking member on the striking surface.

3. An apparatus as claimed in claim 2 wherein the first transducer is in communication with the striking member.

4. An apparatus as claimed in claim 1 including an elongate body of known length, the input means being dispos d at a first end of the body and the spike being disposed at the second end of the body.

5. An apparatus as claimed in claim 4 wherein the input means is a striking means which has an arm which is pivotably engaged with the elongate body at a first end and has a striking member at a second end, there being a mechanism for pivotably moving the striking member so that it can be caused to strike the surface of the fibrous material thereby imparting a sound or shock wave into the fibrous material.

6. An apparatus as claimed in claim 5 wherein the striking member has an acute striking face thereby imparting the sound or shock wave into a small surface area of approximately 1.13 cm^2.

7. An apparatus as claimed in claim 4 wherein the striking means is a mechanical or electromechanical solenoid which can be activated to strike the surface of the fibrous material thereby imparting a sound or shock wave into the fibrous material.

8. An apparatus as claimed in any one of claims 4 to 7 wherein the apparatus includes a spike for penetrating into the fibrous material at a known distance from the input means.

9. An apparatus as claimed in claim 8 wherein the input means is disposed at the first end of the elongate body.

10. An apparatus as claimed in any preceding claim wherein the apparatus includes a means for determining the location of a fibrous member, and an information storage means wherein the location and quality of one or more fibrous members can be stored for retrieval at a later date.

11. An apparatus as claimed in claim 10 wherein the means for determining the location is a Global Positioning System.

12. An apparatus as claimed in any preceding claim wherein the output is a display which indicates a numerical or percentage value representing the absolute or relative quality of the fibrous material.

13. An apparatus as claimed in any one of claims 1 to 11 wherein the output is a display having one or more illumination means for representing the absolute or relative quality of the fibrous material member.

14. A method of testing the quality of a fibrous member as herein defined including:

inserting a spike through any surface material and into a fibrous material of a fibrous member;

creating a sound or shock wave in the fibrous member at a known distance from the spike;

determining the time taken for the sound or shock wave to travel through the fibrous material of the fibrous member from its input point to the spike; and

relating the time taken to reference information to obtain an estimation of the absolute or relative quality of the fibrous member.

15. A method as claimed in claim 14 wherein reference information is historical data stored in computer readable format.

16. A method as claimed in any one of claims 14 to 16 wherein the method is adapted so that the sound or shock wave travels along the longitudinal direction of the fibrous material of the fibrous member.

17. An apparatus as claimed in any one of claims 1 to 13 wherein the fibrous material is a tree, or a log prior to milling.

18. An apparatus as claimed in any ne of claims 1 to 13 wherein the fibrous material is a tree prior to felling.

19. An apparatus as claimed in any one of claims 17 or 18 wherein the fibrous material is the cambium of the tree or log.

20. An apparatus for non-destructive testing of the quality of a fibrous member as herein described with reference to any one of the drawings.

21. A method of testing the quality of a fibrous member as herein described with reference to the preferred examples.

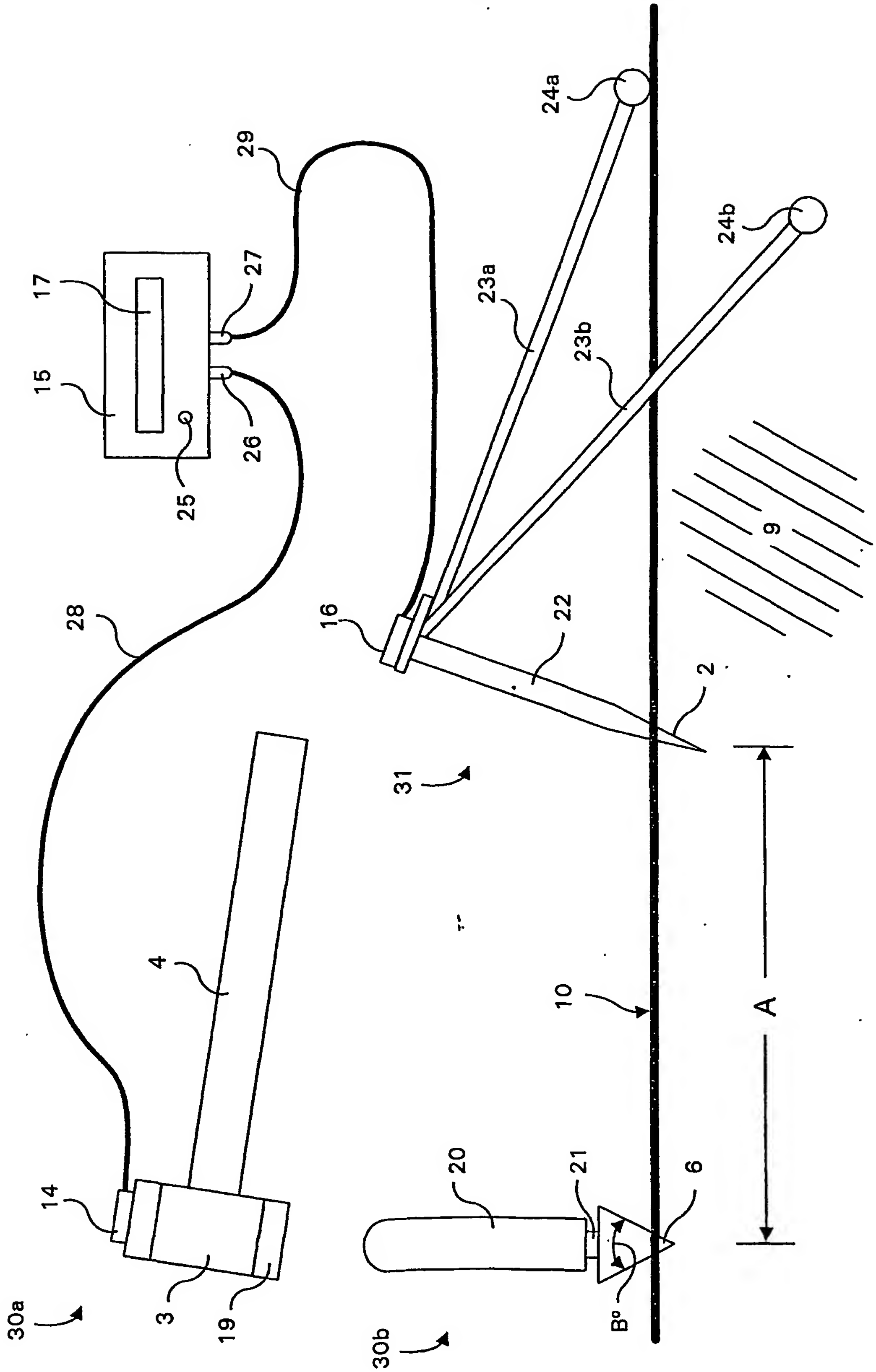
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Figure 1

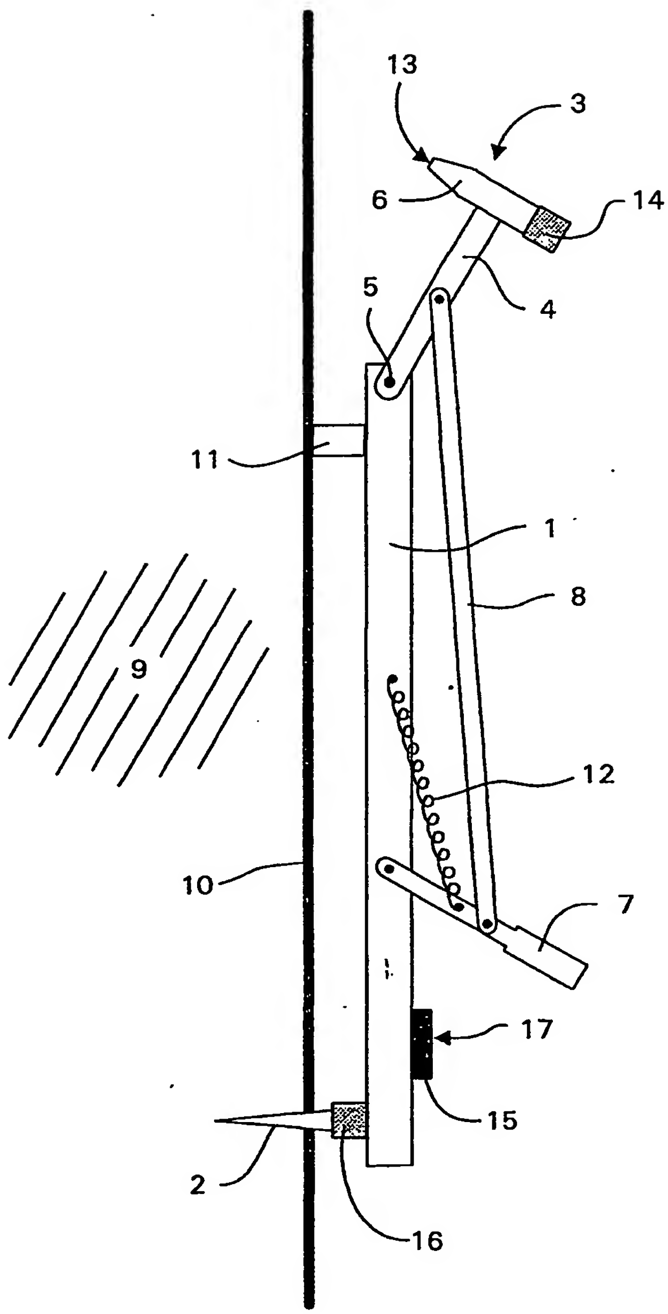

FIGURE 2

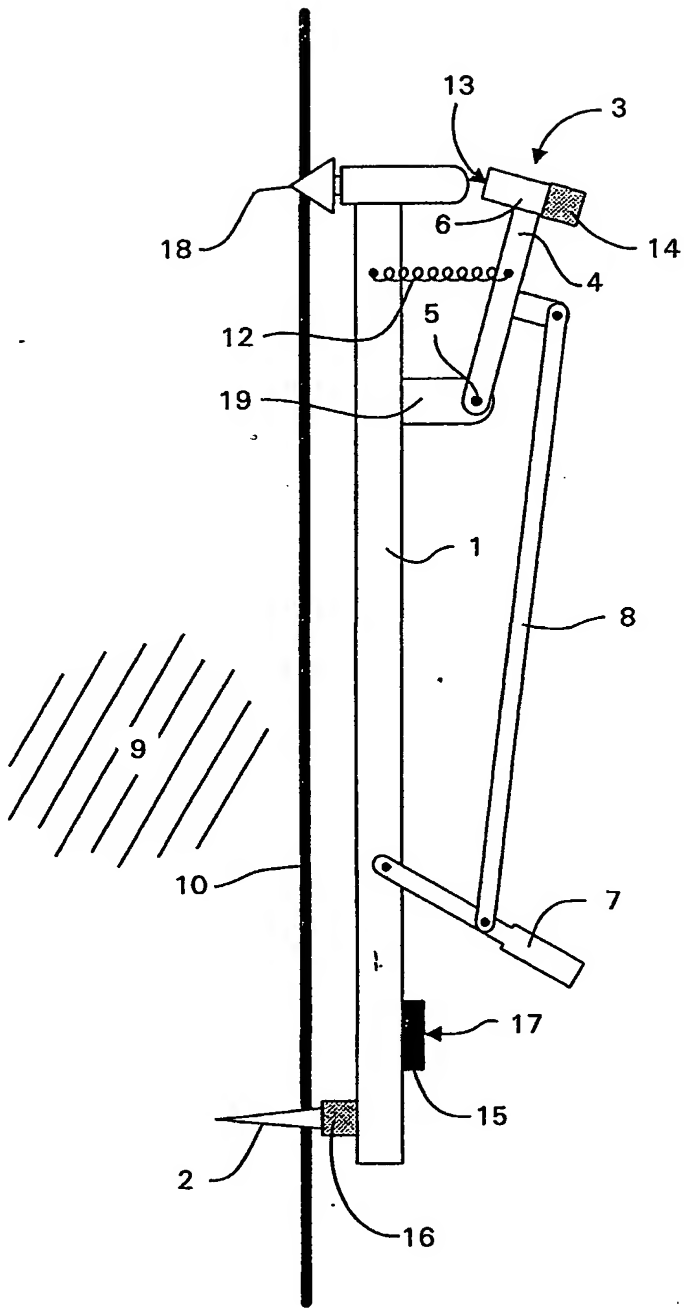

FIGURE 3

INTERNATIONAL SEARCH REPORT	International application No. PCT/NZ01/00205

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. 7: G01N 29/18, 33/46

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

DWPI, JAPIO: G01N 29/-, 33/46 & tree, timber, sound, wave, impact, hammer, strength, stiffness and similar terms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5307679 A (ROSS) 3 May 1994 Whole document	1-21
X	WO 99/44050 A (MASSACHUSETTS INSTITUTE OF TECHNOLOGY) 2 September 1999 Pages 1-8, figures 1-4	1, 4, 8-21
X	WO 99/44059 A (WEYERHAEUSER COMPANY) 2 September 1999 Whole document	1, 10-21

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

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Date of the actual completion of the international search 10 December 2001	Date of mailing of the international search report 12 DEC 2001
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5224381 A (SANDOZ et al) 6 July 1993 Whole document	1, 10-21
X	WO 00/11467 A (CARTER HOLT HARVEY LTD) 2 March 2000 Whole document	1, 10-21
A	EP 261487 A (BIO-KIL CHEMICALS LTD) 30 March 1988 Whole document	1-21

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for thes particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	5307679	NONE					
WO	99/44050	NONE					
WO	99/44059	AU	13932/99	US	6026689		
US	5224381	CA	2045462	EP	456776	NO	912961
		WO	9108477				
WO	00/11467	AU	54542/99	EP	1110083		
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		US	4858469				

END OF ANNEX